B3 Science Solutions for Better Border Biosecurity AOTEAROA NEW ZEALAND

The Fall Armyworm Invasion of New Zealand

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Plant and Food Research, AgResearch

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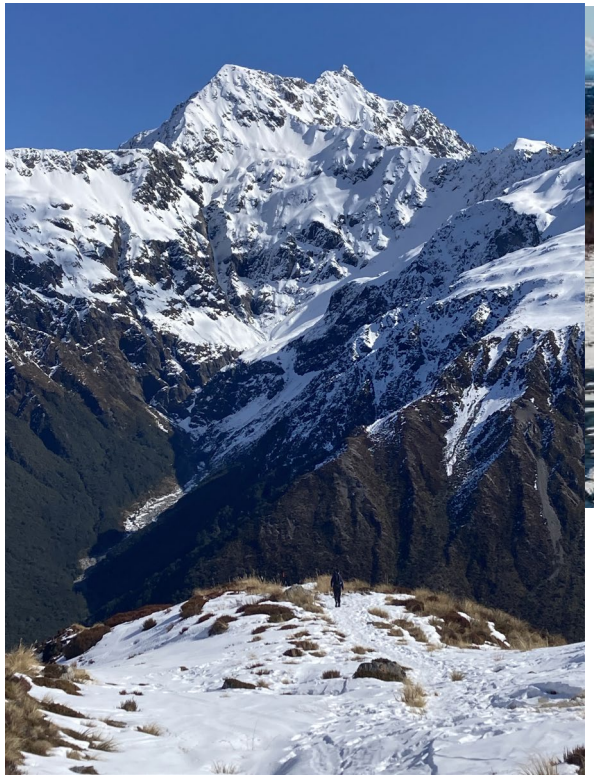
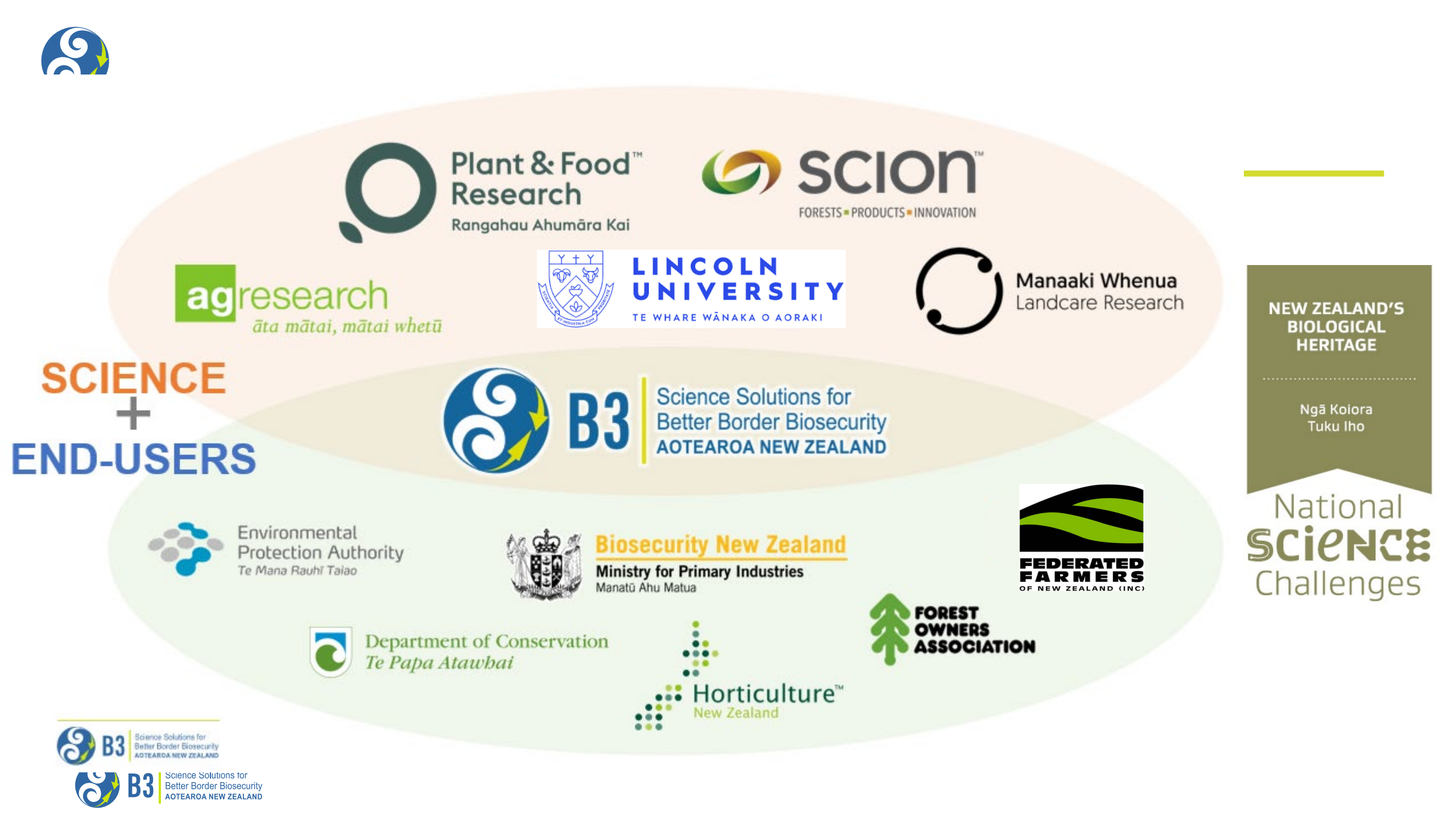
Plant & Food Research Rangahau Ahumāra Kai · agresearch āta mātai, mātai whetū · SCION Forests Products Innovation · Manaaki Whenua Landcare Research · Lincoln University Te Whare Wānaka o Aoraki

Ministry for Primary Industries Manatū Ahu Matua · Forest Owners Association · Department of Conservation Te Papa Atawhai · Environmental Protection Authority Te Mana Rauhī Taiao · Horticulture New Zealand · Federated Farmers of New Zealand

Mihi pepeha

- Ko Mount Rolleston (Kaimatau) te maunga
- Ko Waimakariri te awa
- Ko Haraway/Atlantis te waka
- Ko Wīwī huguenot te iwi
- Ko David (Teulon) toku ingoa





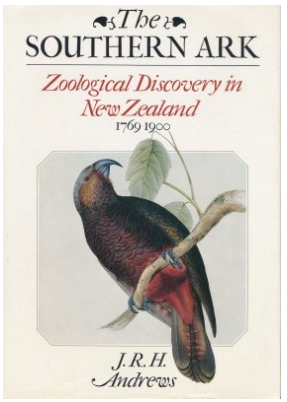
B3 Science Solutions for Better Border Biosecurity AOTEAROA NEW ZEALAND

The Fall Armyworm Invasion of NZ

- NZ biosecurity context
- Pre-amble and initial incursion
- Government and industry response
- Science response

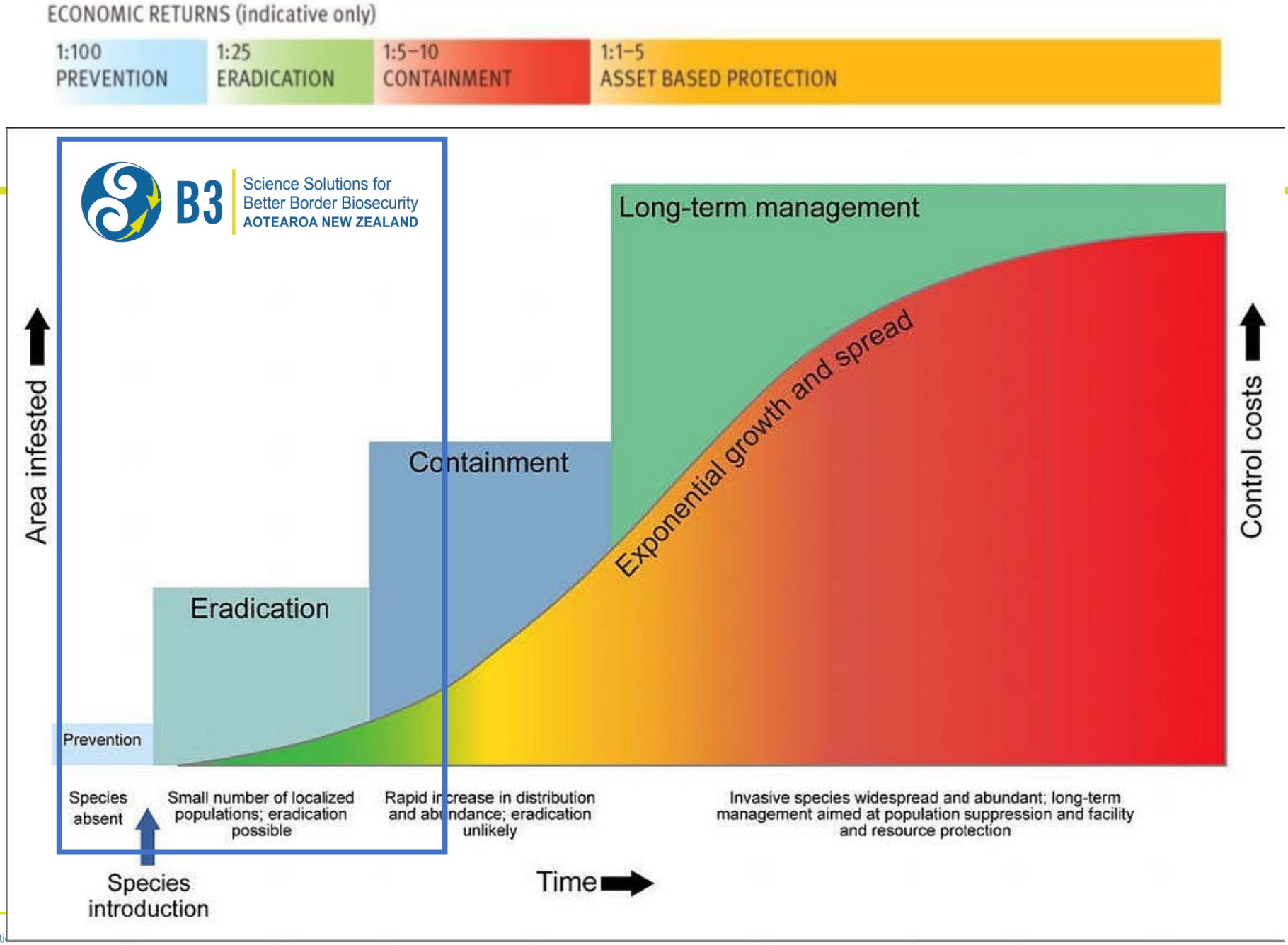
Importance of biosecurity to Aotearoa NZ

- Valued primary sector (incl. plant based economy)
  - Pasture/forage, forestry, cropping, horticulture
  - 6.8% directly to GDP
  - Another 17% indirectly to GDP
  - Two-thirds merchandise exports
- Valued natural systems
  - Recognised world ‘hotspot’ for biodiversity with high endemism
  - Social & cultural importance to Māori and pakeha
- Tourism
  - Up to 5.5% directly to GDP
  - Another 2% indirectly to GDP
  - Largest single export earner



Better Border Biosecurity

- Passenger
- Mail
- Craft
- Cargo
- Environment


ECONOMIC RETURNS (indicative only)
1:100 PREVENTION
1:25 ERADICATION
1:5–10 CONTAINMENT
1:1–5 ASSET BASED PROTECTION
B3
Science Solutions for Better Border Biosecurity
AOTEAROA NEW ZEALAND
Long-term management
Exponential growth and spread
Containment
Eradication
Prevention
Area infested
Control costs
Species absent
Small number of localized populations; eradication possible
Rapid increase in distribution and abundance; eradication unlikely
Invasive species widespread and abundant; long-term management aimed at population suppression and facility and resource protection
Species introduction
Time
Sources: National Invasive Species Council; U.S. Department of Agriculture; National Park Service; U.S. Fish and Wildlife Service; Rodgers, L, South Florida Water Management District; Department of Primary Industries, State of Victoria, Australia; and GAO. | GAO-16-49

THE NZ BIOSECURITY SYSTEM

Biosecurity New Zealand
Tiakitanga Pūtaiao Aotearoa

Layers of risk management

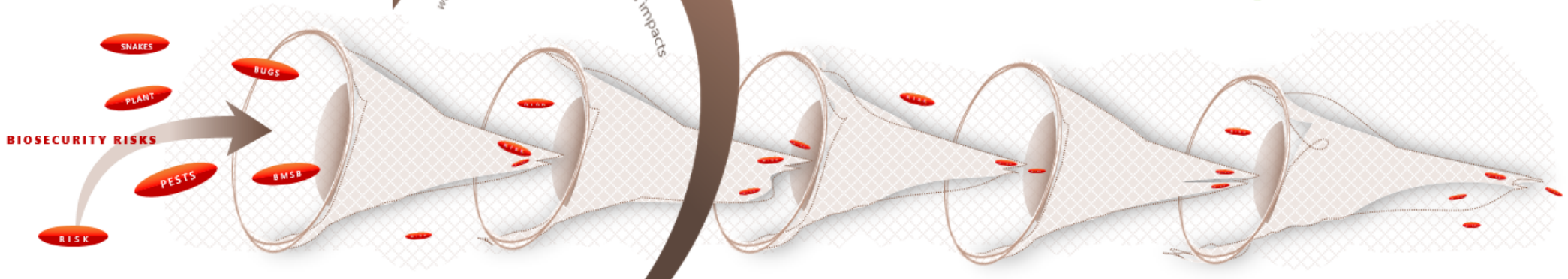
Biosecurity is the exclusion, eradication or management of pests and diseases that pose a risk to the New Zealand economy, environment, and way of life

WE ARE A NET, NOT A WALL

we focus our resources on highest risks and impacts

OUR OUTCOMES

- Our biosecurity system is stronger, including our own business processes
- Imports, and exports to key markets, contribute to New Zealand's growth and prosperity
- The impact of harmful pests and diseases in New Zealand reduces
- Everyone champions biosecurity in New Zealand and owns their responsibilities



MAIL
CRAFT
CARGO
PASSENGERS

PATHWAYS

OFFSHORE | **BORDER** | **WITHIN NEW ZEALAND**

BEYOND NEW ZEALAND

- International standards
- Import risk analysis
- Emerging risk assessment
- Import, craft and facility requirements
- Import permits
- Offshore facilities
- Offshore treatments
- Offshore audits

BORDER

- Pathway profiling
- Intelligence Assessments
- Inspection of cargo, mail & passengers
- Transitional facilities
- Detector dog Programme
- Compliance assessments
- Post entry quarantine
- Diagnostics

SURVEILLANCE & INCURSION INVESTIGATION

- 0800 pest and disease hotline
- Active & passive surveillance
- Diagnostics
- Incursion investigation
- Preparedness

READINESS

- Threat specific and pathway readiness
- Sector relationships & arrangements e.g. Government industry agreement (GIA);
- Response information management systems & processes
- Response capability, capacity & resources
- Simulations and reviews
- On-farm biosecurity

RESPONSE

- Initial response
- Delimiting surveys
- Response and contingency planning
- Response systems
- Containment or eradication
- Diagnostics
- Recovery planning
- Compensation
- Welfare

RECOVERY & PEST MANAGEMENT

- Pest management programmes
- Site led pest management
- Long-term control
- Internal borders & pathway management

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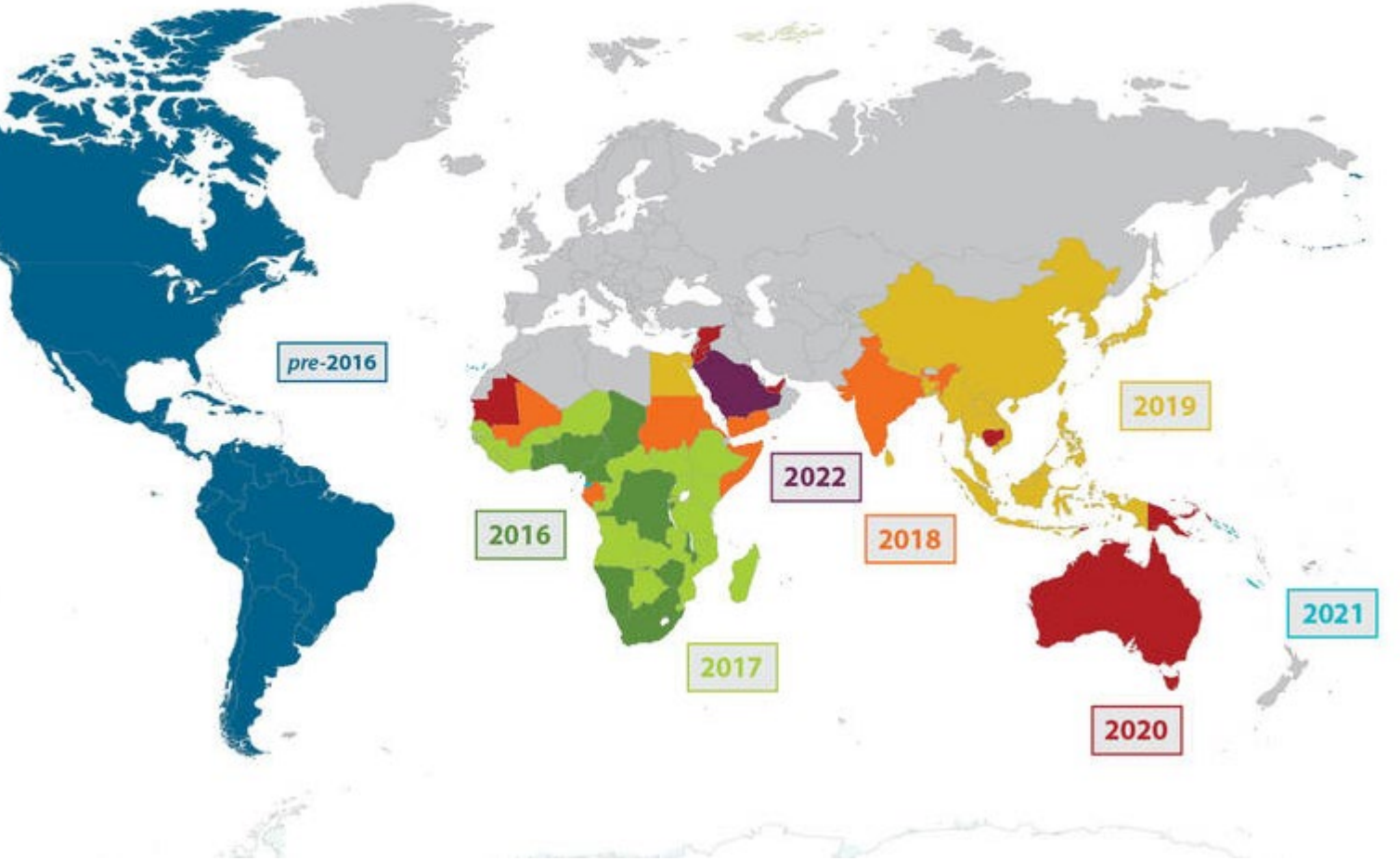
A word cloud of the most important global issues relevant to biological invasions, summarised from an international survey of 240 experts by Dehnen-Schmutz et al. (2018). The font size of each word or phrase is proportional to the number of respondents who rated it highly.

Fall armyworm (*Spodoptera frugiperda*)

- Noctuid
  - Strong flyer 1000+ kilometers
- Origin: Americas
- Up to 350 recorded hosts (maize, sweet corn)
- Tropical origin 12 generations per year
- Difficult to control
  - Insecticide resistance
- Last two decades has been spreading rapidly
  - Africa, India, Asia and Australia

FAW-NZ. Preamble and initial incursion



Attributes used to identify biosecurity hazards to NZ

- Overseas distribution climatically matched with NZ
- Established as non-native in novel regions offshore
- Present in Australia
- Member of same genus present in NZ

Phillips & Vink 2013

FAW-NZ. Preamble and initial incursion

April 2021 Risk Assessment

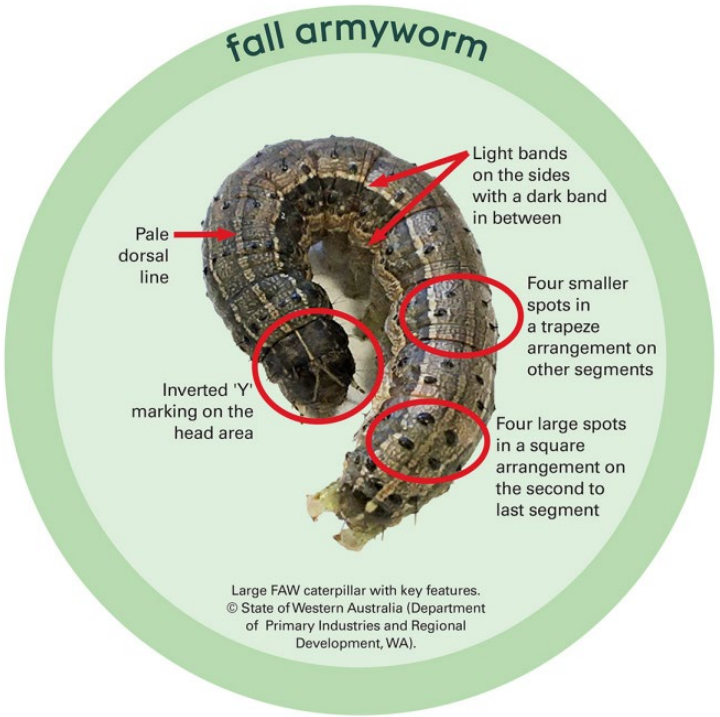
- Economic consequences nationally are considered to be very low, with the potential for low localised impacts
- The overall risk, to New Zealand, from FAW is considered to be very low to low

March 2022 Fact sheet

- … the moth would struggle to establish in NZ, as areas with preferred hosts do not necessarily have the correct climate to suit fall armyworm
- … overall risk was assessed as low because consequences nationally are considered to be very low, with the potential for low localised impacts

Biosecurity New Zealand
Tiakitanga Pūtaiao Aotearoa

Pest Risk Assessment: *Spodoptera frugiperda* (Fall armyworm)

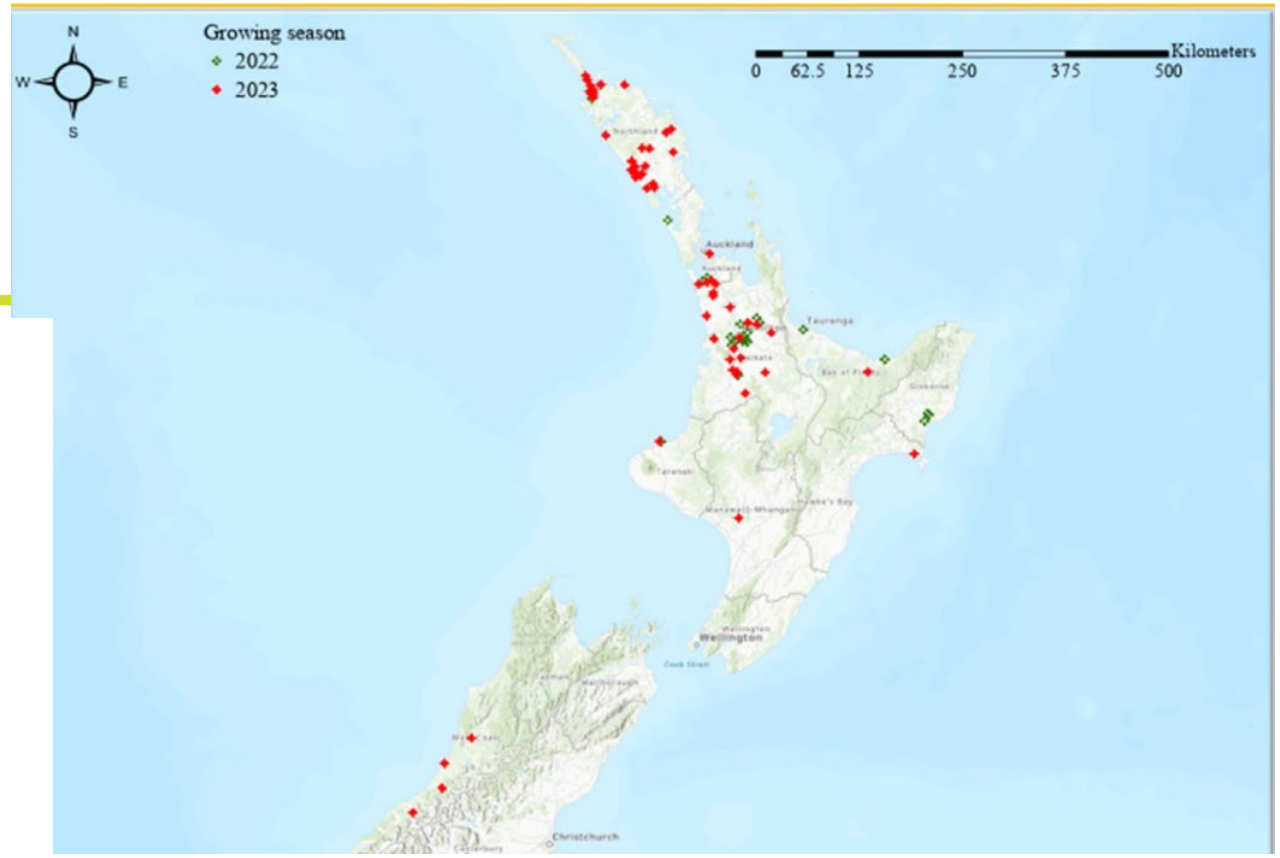


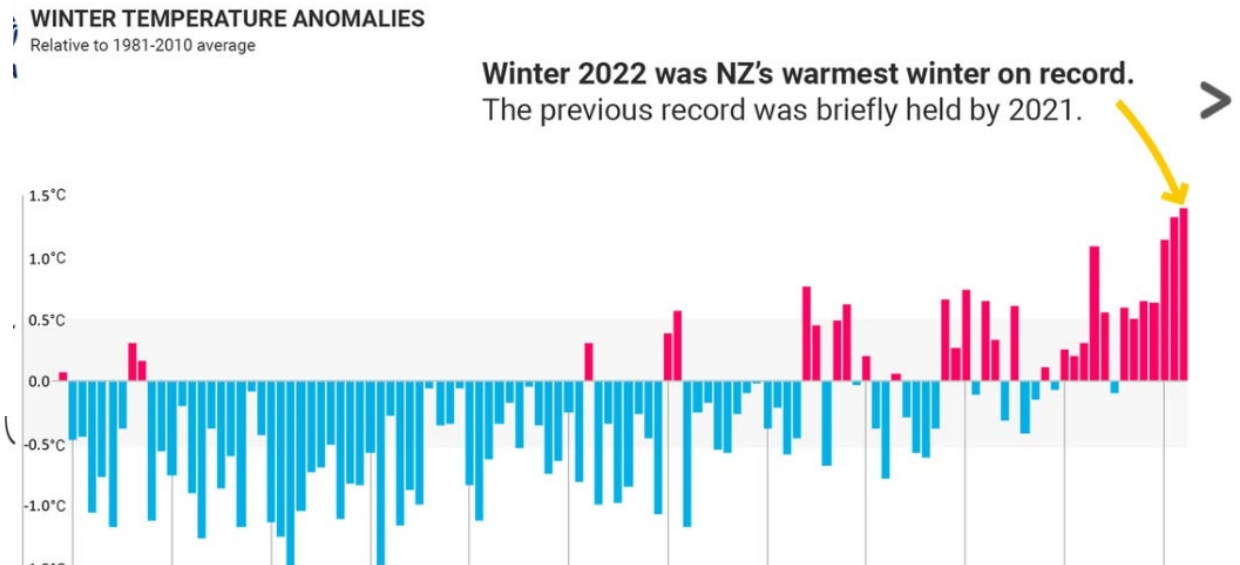
Large FAW caterpillar with key features.
© State of Western Australia (Department of Primary Industries and Regional Development, WA).

Spodoptera frugiperda (Fall Armyworm (FAW)) Risk Assessment						
Risk assessment stage	**Pathway**	**The level of risk is considered:**				
		Negligible	**Very Low**	**Low**	**Moderate**	**High**
Likelihood of entry	Wind dispersal				■	■
	Nursery stock			■	■	
	Fresh produce			■	■	
	Fresh cut flowers and foliage for decorative purposes			■		
	Passengers and inanimate objects			■		
Likelihood of entry of specific life stages	Egg masses			■	■	
	Larvae			■	■	
	Pupae		■			
	Adults				■	■
Likelihood of exposure	Wind dispersal				■	■
	Nursery stock			■	■	
	Fresh produce			■	■	
	Fresh cut flowers and foliage for decorative purposes			■	■	
	Passenger sand inanimate objects		■	■		
Likelihood of establishment	Egg masses			■	■	
	Larvae			■	■	?
	Pupae			■	■	
	Adults			■	■	
Likelihood of spread	Established populations					■
Potential magnitude of consequences	Economic		■	■		
	Environmental		■		?	
	Sociocultural		■			
	Human health	■				

FAW Timeline

- 2020
  - Unwanted organism with quarantine & regulated pest status
- Late summer/early autumn 2022
  - Egg mass on spongy moth trap (March)
  - Field crop records in North Island (April/May)
  - Response initiated (May)
- Winter 2022
  - Warmest on record (June, July, August)
- Spring/summer 2022-23
  - Field crop records from throughout NZ (from November 2022)
  - Transition to long term management (April 2023)
- Winter 2023
  - 5th warmest winter, late frosts in Northland
- Spring 2023
  - No detections so far





Operational Response: Government Industry Agreement (GIA) for Readiness & Response

GIA
Biosecurity through Partnership

- Biosecurity NZ (65% of response costs)
- Industry (35% of response costs)
  - Foundation for Arable Research
  - Vegetables NZ
  - Process Vegetables NZ

- Day to day management of the response – incl. WRT to eradication
- Surveillance
  - Public reporting (Biosecurity NZ)
  - Pheromone trapping
  - General crop scouting
- Extension
  - Workshops & field days, fact sheets
  - Advice on management
- Funded some applied research

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Biosecurity New Zealand Ministry for Primary Industries Manatū Ahu Matua
FAR®
Vegetables NEW ZEALAND Inc
Process Vegetables NZ

Science Response

Better Border Biosecurity (B3)

- Australia FAW expert presents at B3 Science Partnership Forum – October 2020 (Helen Spafford)
- Session at International Congress on Biological Invasions (ICBI2023 – May 2023)
- Funded and supervised rangatahi (young Māori students) to develop culturally directed engagement with iwi in Northland

B3 FAW Biosecurity Science Consultative Group – initiated May 2022

- researchers from NZ, Australia and Asia

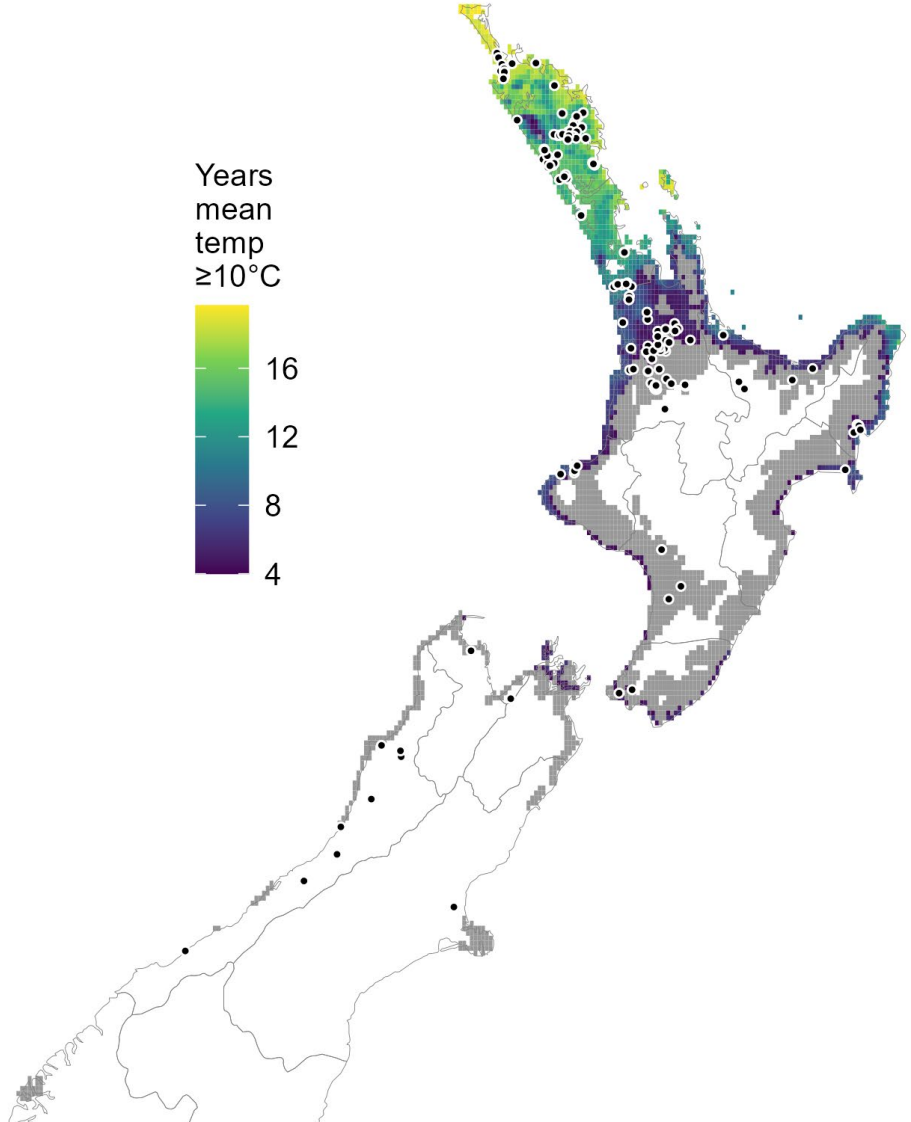
Science projects proposed

- Climate modelling: determine overwinter location, number of generations per year in different localities
- Spring assessment of flights to provide further evidence of overwintering
- Internal pathways: Migration from overwintering areas to other locations in NZ
- Genomic analysis to confirm origins and presence of resistance genes
- Potential impact on plants of value to Māori (taonga) especially those found in Te Tai Tokerau/Northland

Overwintering of FAW in NZ

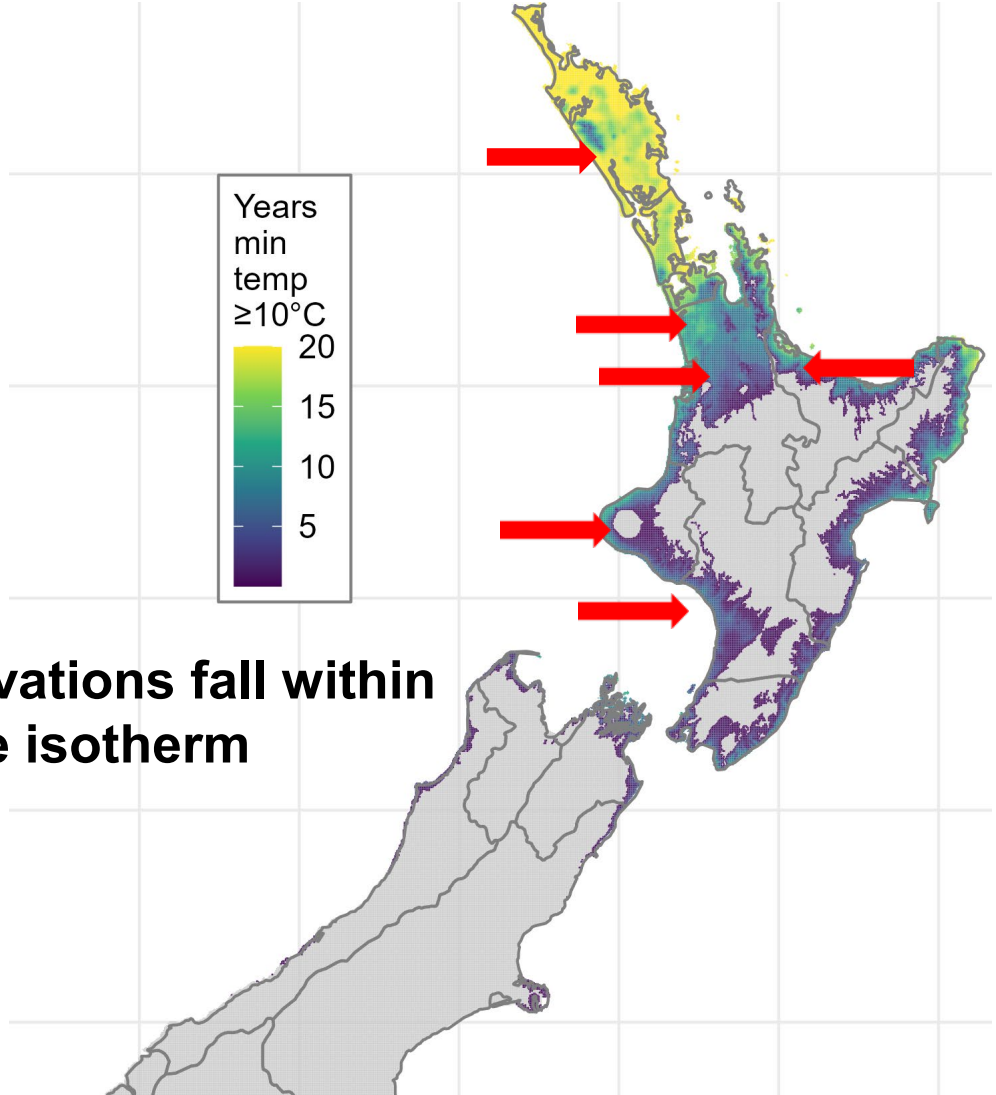
agresearch
āta mātai, mātai whetū
Craig Phillips

- Contrast continental vs temperate climate (generally higher minimum temperatures)
  - Are NZ winters cold for long enough to kill FAW?
  - Where in NZ is it likely to persist?
  - How much will FAW's winter range in NZ vary with annual climatic fluctuations and longer-term climate change?
- Tested various models using year round distribution data from USA and China
- "Strong correlation" between the 10^{O}C winter isotherm and areas FAW seems to overwinter
  - Incl. many areas outside of Northland
  - Other evidence for internal pathways
  - Between 1 and 4 generations in 2022-23 season



Spring FAW monitoring systems

- Crop scouting was always more effective at detecting FAW than pheromone trapping
- November-December 2022
  - Northland
    - 30 vs 9 records
  - Auckland
    - 3 vs 0 records
  - Waikato
    - 19 vs 0 records
  - Bay of Plenty, Taranaki, Whanganui, Hawkes Bay
    - 5 vs 0 records



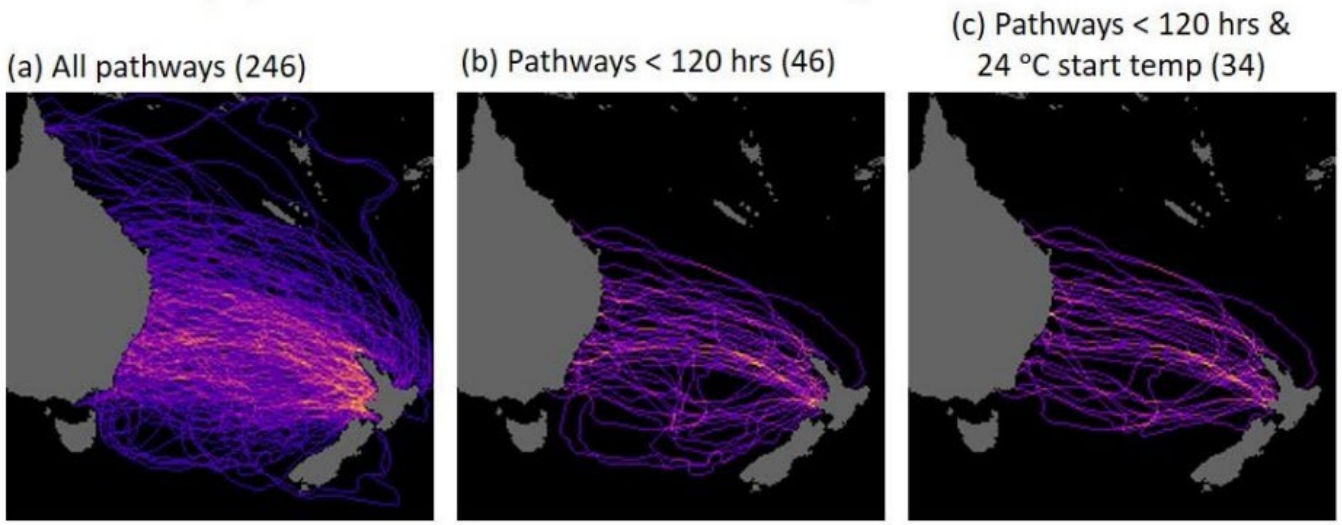
All observations fall within 10 degree isotherm

Pathways to and with NZ

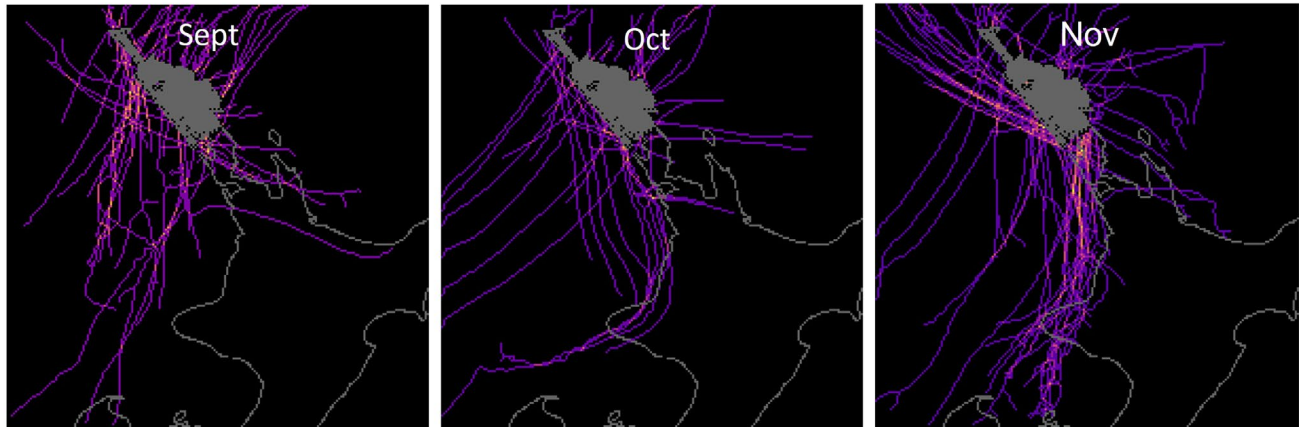
Ilze Pretorius

- … introductions were most parsimoniously explained by anthropogenic-assisted spread (Rane et al. 2023)
- widely distributed initial findings in NZ very suggestive of aerial pathway
- evidence for long-distance aerial dispersal of invasive insects and wildfire smoke, a potential carrier of invasive species, is driven by atmospheric pathways known as Lagrangian coherent structures (LCS) (airbridges)

November – April, 2015 - 2019: Australia mainland source-region



LCS airbridge connections from Northland for the months Sept, Oct and Nov for 2019-2021



Impact on plants of value to Māori

David Teulon

- Conventionally trained scientists in Aotearoa NZ are increasingly challenged to consider Te Ao Māori and mātauranga in their research
- FAW has been reported from >350 host plant species in 76 plant families but principally from Poaceae, Asteraceae, and Fabaceae
- Pest pressure from FAW is likely highest in Te Tai Tokerau/Northland due to the warmer conditions.
- Given the high proportion of iwi/Māori in this area, there may be a disproportionate impact of FAW on plants of value to iwi/Māori
- So far no FAW have been reported on native plants (but limited looking)

Ngā Tamariki o te wao nui o Tane (native plants)	**'Acutely threatened' and belong to genera that are known FAW hosts**: • *Asplenium pauperequitum* (Poor Knights spleenwort), *Hibiscus diversifolius* (native hibiscus), *Pittosporum ellipticum*, *Senecio scaberulus* (fireweed)
Rongoā (medicinal plants)	**Plant in genera that FAW has been recorded:** • tarata (*Pittosporum eugenoides*), kawakawa (*Piper excelsum*), and kōhia (*Passiflora tetrandra*) **Plants in families that FAW has been recorded:** • rata (*Metrosideros robusta*), Ti kouka (*Cordyline australis*), manuka (*Leptospermum scoparium*), kowhai (*Sophora microphylla*), mahoe (*Melicytus ramiflorus*), rangiora (*Brachyglottis repanda*)
Raranga (weaving plants)	**Plant in families that FAW has been recorded:** • kiekie (*Freycinetia banksia*), kāretu (*Hierochloe redolens*)
Māra Kai (community gardens)	**Plant species that FAW has been recorded:** • kānga (Indian corn, maize) (*Zea mays*), kūmara (*Ipomoea batatas*), taewa (*Solanum tuberosum*), kamokamo (*Cucurbita pepo*), and hāria/paea/nīko/puka/rearea/nanī/pora (wild cabbage, Māori cabbage) (*Brassica oleracea*) **Plants in families that FAW has been recorded:** • poroporo (*Solanum aviculare*), hue (bottle gourd) (*Lagenaria siceraria*), kōkihi/rengamutu (NZ spinach) (*Tetragonia tetragonoides*), puha/rauriki/pororua (*Sonchus* spp.), pikopiko mauku/mouku (hen & chicken fern) (*Asplenium bulbiferum*), paretao/pānako (Shining spleenwort) (*Asplenium oblongifolium*), nīkau (*Rhopalostylis sapida*)

FAW hosts in New Zealand

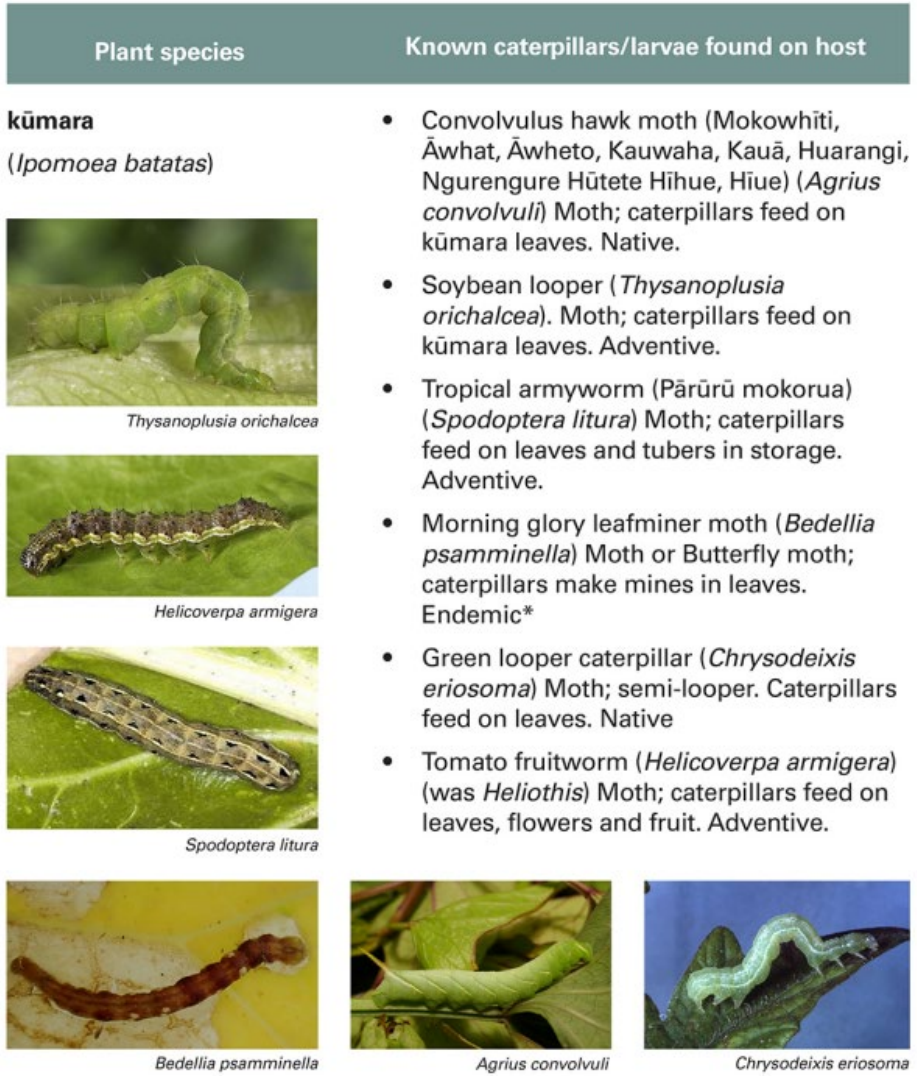
General observations

- Vast majority of observations/records were on maize or sweet corn (140/149 or ≈ 94%)
- Other hosts
  - Yams (*Oxalis tuberosa*)(1/149)
  - Potato (*Solanum tuberosum*) (1/149)
  - Chicory (*Cichorium intybus*) (1/149)

Identification of FAW and similar species

Frances MacDonald

- Multiple native plant species and plants of significant value, in particular to Māori, are identified as at risk to FAW
- As part of surveillance, correct identification of the insects present on these native/taonga plants is important
- Poster presents 10 plant species and their known butterfly/moth/caterpillar fauna in NZ
- Species are drawn from the Pittosporaceae, Piperaceae, Passifloraceae, Convulvulaceae, Poaceae, Solanaceae, Curcurbitaceae, Brassicaceae and Asparagaceae
- Producing resources that serve broader interests and audiences, including iwi/Māori-focused issues, are needed



Plant species	Known caterpillars/larvae found on host
kūmara (*Ipomoea batatas*)	• Convolvulus hawk moth (Mokowhīti, Āwhat, Āwheto, Kauwaha, Kauā, Huarangi, Ngurengure Hūtete Hīhue, Hīue) (*Agrius convolvuli*) Moth; caterpillars feed on kūmara leaves. Native. • Soybean looper (*Thysanoplusia orichalcea*). Moth; caterpillars feed on kūmara leaves. Adventive. • Tropical armyworm (Pārūrū mokorua) (*Spodoptera litura*) Moth; caterpillars feed on leaves and tubers in storage. Adventive. • Morning glory leafminer moth (*Bedellia psamminella*) Moth or Butterfly moth; caterpillars make mines in leaves. Endemic* • Green looper caterpillar (*Chrysodeixis eriosoma*) Moth; semi-looper. Caterpillars feed on leaves. Native • Tomato fruitworm (*Helicoverpa armigera*) (was *Heliothis*) Moth; caterpillars feed on leaves, flowers and fruit. Adventive.

Genomic analysis

In native range	Fall armyworm	In invasive ranges
	Oviposition: egg clutches on plants	
Egg clutches found on many plant species (1, 58, 136)		Egg clutches found in corn and sorghum fields, but also in other crops (19, 114, 122)
Two strains, C-strain and R-strain, with up to 2% genomic differences (50), although hybridization occurs between strains (10, 127)	**Larvae** 	No separate strains (127, 153)

Annual Review of Entomology

Spodoptera frugiperda: Ecology, Evolution, and Management Options of an Invasive Species

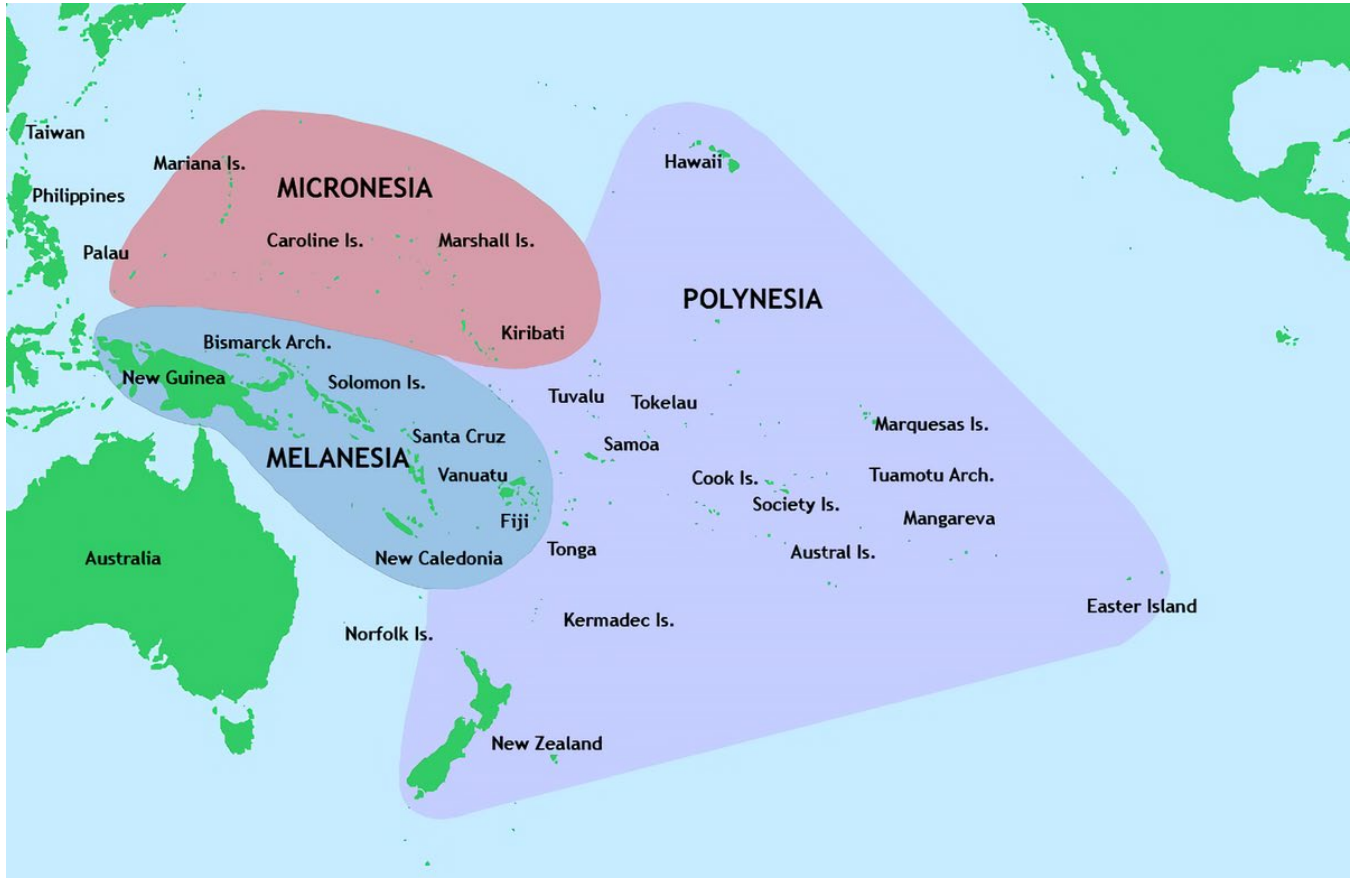
Wee Tek Tay,[1,*] Robert L. Meagher Jr.,[2] Cecilia Czepak,[3] and Astrid T. Groot[4]

NZ Pukeatua (nr Hamilton)

- pupae collected in May 2022
- from a maize farm
- based on the mt-COI sequence
  - ‘R-strain’

FAW Pacific Island Countries and Territories

- Incursions of FAW: Papua New Guinea, Solomon Islands, Vanuatu
  - Investigating the biology and ecology of FAW in Pacific island states, including its population dynamics, host range, and natural enemies
  - Assessing the effectiveness of different surveillance and monitoring methods for FAW in Pacific island states
  - Developing and evaluating early warning systems for FAW in Pacific island states
  - Raising awareness and training farmers and other stakeholders on FAW management in Pacific island states

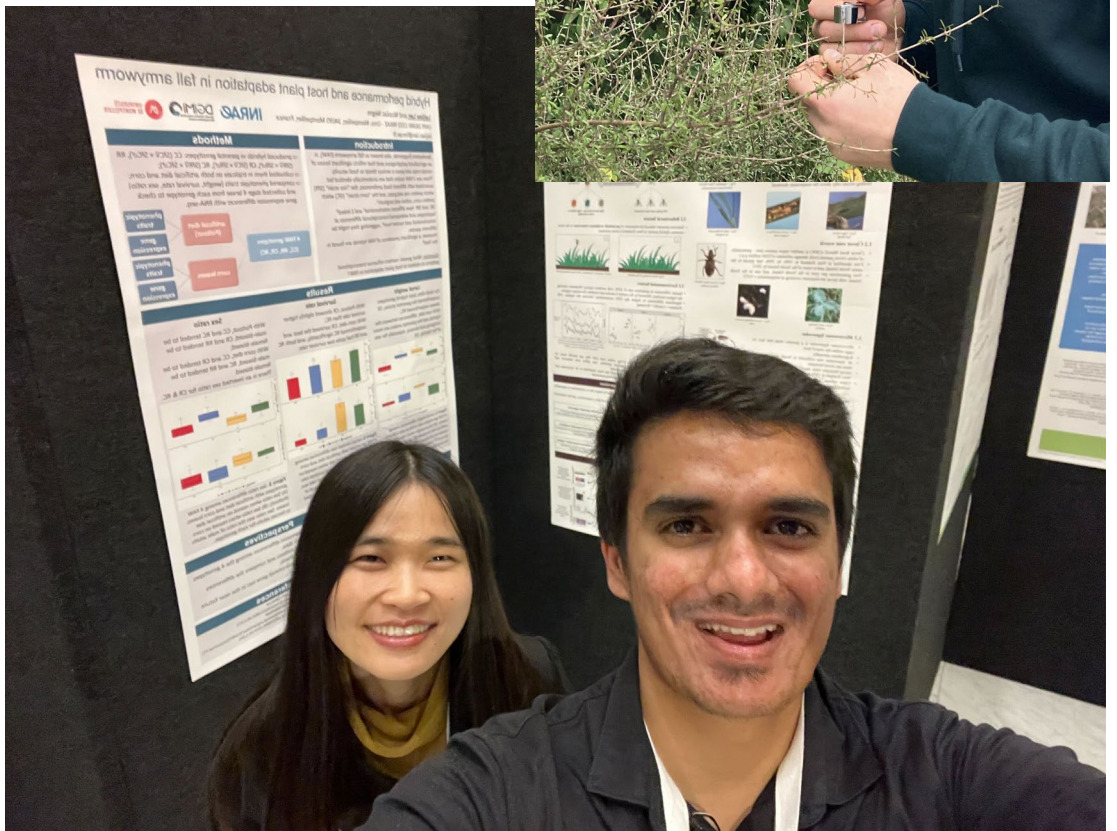


Summary

- FAW is now firmly established in NZ
- FAW is largely associated with maize and sweetcorn
- Extent to which FAW will overwinter and develop damaging populations in New Zealand is still being determined
- FAW has the ability to over winter in New Zealand
  - 10 degree Isotherm
- Ability to overwinter will increase with climate change
- A pest in some years than others

Collaborations with France

- Durmonde D'Urville / Franco-New Zealand Hubert Curien Partnership
  - The potential of genomic tools for understanding and managing invasive species
  - INRAE, ANSES. Uni Waikato, MWLR, PFR
- Horizons EU (Pillar 2)
  - NZ now an Associated Member
  - Automatic eligibility: Fiji, Kiribati, Marshall Islands, Micronesia, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu,



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Thank you

Plant & Food Research Rangahau Ahumāra Kai

agresearch āta mātai, mātai whetū

SCION

Manaaki Whenua Landcare Research

LINCOLN UNIVERSITY TE WHARE WĀNAKA O AORAKI

Ministry for Primary Industries Manatū Ahu Matua

FOREST OWNERS ASSOCIATION

Department of Conservation Te Papa Atawhai

Environmental Protection Authority Te Mana Rauhī Taiao

Horticulture New Zealand

FEDERATED FARMERS OF NEW ZEALAND

- Fall armyworm (FAW), *Spodoptera frugiperda* (Lepidoptera: Noctuidae) can feed on over 350 plant species and is a pest of corn/maize and other crops. It is native to the Americas and has recently spread to Africa, India, China, Japan, Southeast Asia, Indonesia, Australia and New Zealand. In New Zealand it was first found at Tauranga in March 2022, and was assumed to have been wind-blown from Australia. By April 2022 it had been recorded at numerous locations in the upper North Island. This paper documents the initial discovery of FAW in New Zealand, the government and industry incursion response, and summaries information on its entry pathway, initial internal spread, overwintering ability, host plants, and potential impact – including to New Zealand indigenous plant species. FAW is a sub-tropical/tropical noctuid insect, and the extent to which it will overwinter and develop damaging populations in New Zealand is still being determined. FAW was unable to be eradicated, is now well established, can survive the winter in northern parts of the country, and is now under long term management.